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# Accurate localization technique for stamping sheet metal parts with complex surfaces

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Sheet metal stamping processes involving three-dimensional parts have been appealing various engineering research efforts, especially when it comes to high strength steels. Particularly, for those with complex, sculptured surfaces, the springback phenomena causes non-trivial geometry problems in both evaluation and compensation of geometric distortions. Computer simulations based on Finite Element (FE) improve and enhance stamping methods in order to achieve required dimensional tolerances and reduce time-consuming design and production stages. FE results are compared with the desired product geometry for validation of the simulation accuracy, as well as indicating design status with respect to part geometry. In these assessments, part geometric localization at design space is a very critical step that design engineers must pay great attention in positioning both tool and part surfaces. In this study, a new surface localization methodology is presented for comparison of FE analysis results with non-contacted scanned part surfaces. In this methodology, the gap projection and centroid superposing technique are used for localizing the complex surfaces in a design space and applied to the process design steps of a roof stiffener automotive part. An assessment of shape distortion indicators shows that the proposed methodology can localize the surfaces accurately and much efficiently than conventional methods.

**Keywords:** Sheet stamping, Computer simulation, FEM, Surface localization, Deviation analysis

## 1 Introduction

A successful sheet metal forming contains a final product that has the necessary geometric tolerances, and a defect-free surface. Method engineers must ensure a reliable forming process for the manufacture of sheet metal stamping dies. An accurate approach for the stamping process is essentially sought in the early stages of die-face design in order to decrease the cost of the stamping tool. Under time-to-market criteria, catching stamping constraints while minimizing the tooling cost, and reducing the number of operations, is usually not an easy engineering problem. The shape distortion and formability analysis of the material, and determination of process parameters such as thickness, blank holder force, friction conditions, etc. for further engineering studies are critical for controlling the lead-times for die manufacturing.

The relationship between these design parameters can only be described by using analytical expressions which exist rarely, obtaining tooling elements with desired dimensions follows some costly try-and-error procedures in the industry. On the other hand, computer applications generally help design engineers to understand material behavior under deformation for a given geometric mapping, and to determine correlations among the process parameters and mechanical properties. Computer applications become a state-of-art tool for die tooling design by shifting the design parameters into a less-costly virtual environment in the present technology[1-3]. Belong these applications, finite element (FE) analysis has the widest usage area[4].

During sheet metal stamping operations, obtaining formability and shape distortions of the material accurately is a critical stage in stamping tool design, and it is relatively difficult to predict shape distortions like springback, due to its unbalanced mechanism. This type of deformation appears naturally due to unbalanced stresses over the sheet metal when the removal of the die tools, and hence the springback deformation is unavoidable. The springback deformation becomes a more critical problem when it comes to high strength steels[5]. Besides, other important factors have an effect on springback deformation like process parameters and scaling factor, etc.[6-8]. The increasing number of stamping parts made of lightweight materials, such as high-

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strength steel, forces the design engineer to eliminate the springback deformation effects on the geometric tolerances of the final part during the early stages of the design processes. Finite Element Analysis (FEA) help the engineer in these cases. However, FE prediction results must compatible with the real part dimensions to make acceptable decisions in the design stages. The accuracy of a simulation means the degree of experimental surface representation by FEA result.

Today, complex experimental surfaces can be measured using advanced technologies[9]. These technologies can be grouped as contacted and contact-free methods. Contacted methods like

Coordinate Measurement Machines (CMM) can measure specific areas or a point on the desired location. In sheet metal stamping processes, since springback shows a distributed deformation behavior all over the part geometry, contacted measurements loses their advantage. Design engineers generally desire contact-free methods like laser or optical scanning to obtain surface information all over the part. In laser scanning, a laser line moves over the part, CCD cameras record and save the deformation of the laser line, and thus, surface information is transferred to a computer environment. In optical scanning, a cluster of lights is projected on the part, and CCD cameras record the deformation of this cluster similar to laser scanning. All surface information can be obtained using contact-free methodologies. Stamped parts can be transferred into the computer environment using these methods. Then, the scanned surface is used as a reference surface to evaluate the accuracy of FEA results.

The process of surface comparison is another critical stage of the die-design cycle. Deviation analysis, which is a proven method for assessing the accuracy of diverse physical objects[10], is generally used by design engineers in compatibility analysis of virtual experimental and FEA surfaces.

An accurate FEA is not only dependent on parameter calculation or material modelling, but also the localization of comparison surfaces is critical, and affects directly the accuracy of the results. Localization of complex surfaces is generally obtained by superposing the coordinate systems of FEA results and experimental surfaces[11-13]. Although this method can be used in simple geometries, its function is lost in complex phases. Improvement in computer software technologies brings more user-friendly interfaces. Nowadays, CAD software can localize comparison surfaces utilizing their element geometries[14]. Localization is performed by determining and superposing common elements in comparison surfaces. This method is named as "best-fit”. Although "best-fit" is very effective for complex surface comparison[15-17], it has a disadvantage of not being able to be controlled by the user in each step of the process.

In this study, a localization methodology, using the gap projection technique and calculating the surface centroids, is proposed. This novel methodology allows users can compare different surfaces by superposing their centroids. It is capable of using either complex or simple surfaces as well as and translating them in the workspace. Users can work with different mesh designs (one of the surfaces can include triangular mesh design, and another can include quadratic mesh or composite mesh design) or different geometries (the method can localize wholly different surfaces) easily. This method can perform its ability to scanned real parts or FE solutions. Hence, users can easily compare the experimental and FE surfaces accurately and can determine the prediction accuracy of the simulations. The experimental results of this study obviously show the superiority of the proposed localization methodology on other methodologies in the literature (like the best fit or superposing coordinate systems).

## 2 Materials and Methods

### 2.1 Proposed Methodology

In the stamping industry, the geometric differences between two sheet metal parts for control purposes usually assessed by choosing one of the following two measures;

a) Dimensional measures (linear or angular),
b) Shape measures: Section cuts

These two surfaces are initially positioned by an appropriate choice based on their shape, and consequently, are datumed via these approaches. Then, a linear or angular reference dimension is determined to describe the differences between two surfaces. Figure 1 shows an example for V-channel forming. The geometric parameters $\theta$ and $\rho$ in the figure refer to the angle between the wings of the V-shape and the radius of the bottom area of the part, respectively. These parameters are related to the springback amount in the product geometry after forming operation and can be used to compare FE results with the experimental geometry. An example of section cuts utilization for displacement analysis of an industrial part geometry is shown in Fig. 2. Geometries having complex forms with symmetry can be compared using section cuts. Although the shape differences can be determined by using geometric parameters shown in Figs 1 and 2, some complex forms cannot easily be determined by geometric parameters or section areas. Hence, a different surface comparison methodology required.

Although analytical surfaces can mathematically be compared with each other using standard tools of analytical geometry, the description of surfaces in real die-faces is usually limited to the initial CAD stage, and more often, direct use of NURBS-type surfaces in die surfaces may not be feasible due to limitations of CAD software or execution time for the surface construction[18-20]. Furthermore, it is more common to have a group of points, usually from a surface scanning, instead of surfaces. In other words, a point cloud, of which surface construction in a CAD environment is usually troublesome and time-consuming, has been forced to handle. Therefore, it becomes more practical to consider linear patches (three-point or four-point segments) for the geometric analysis of surface differences. This computational approach does not pose any practical problem when dealing with either CAD, FEA or reverse engineering stages for die-face construction and process feasibility of stamping surfaces. Therefore, it is of practical significance that two surfaces subject to shape deviation analysis are composed of point clouds and their geometric differences can be analyzed assuming both surfaces are defined with linear (patch) segments.

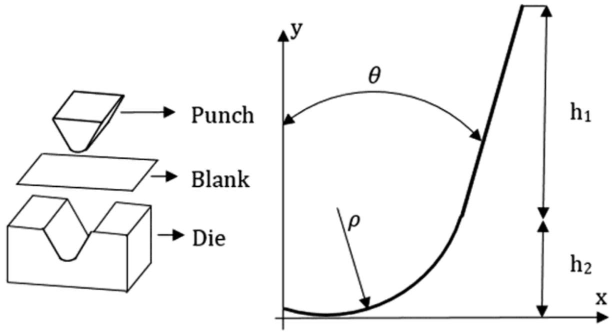

Fig. 1 — Definition of angular springback measures for V-channel forming. Geometries can be compared with each other using these geometric parameters.

In this study, it is assumed that two surfaces or two groups of surfaces are composed of triangular

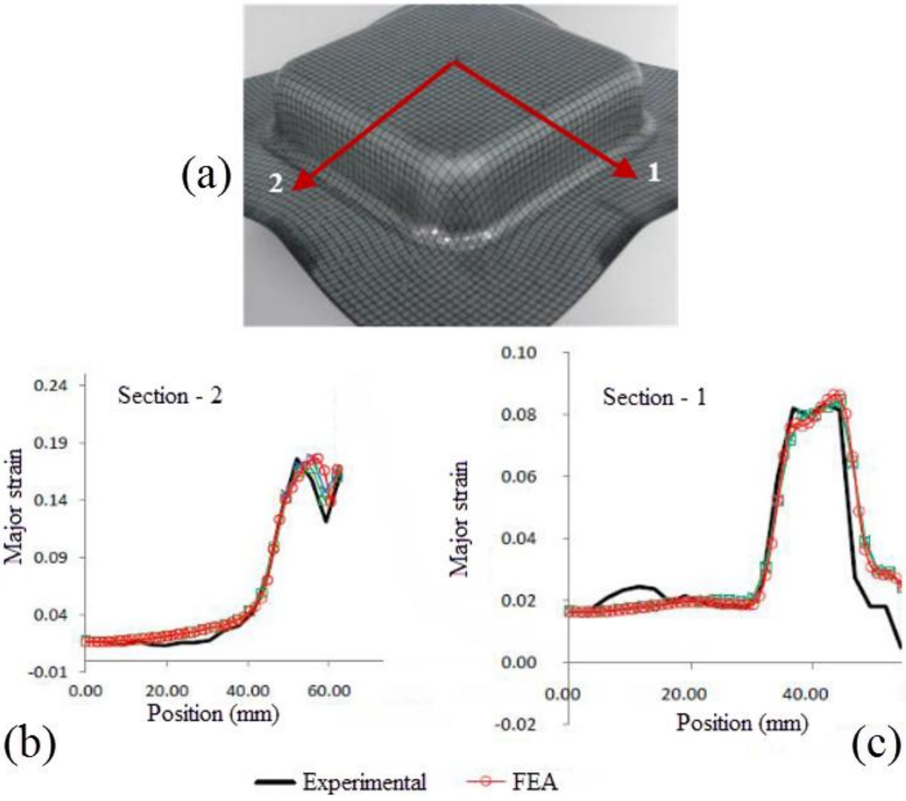

Fig. 2 — (a) Section cuts for displacement (as strain) purposes for an industrial square drawing part which has a symmetry condition. (b) major-stain-position results for Section-2, and (c) major-stain-position result for Section-1.

segments and subjected to shape deviation analysis. As the first step, one surface is chosen to be the reference surface for which the other surface will be evaluated, and the other surface is called as the measured surface. In the same way, the triangular segments constituting the master surface are called reference segments, and those belonging to measured surfaces are the measured segments. Figure 3 schematically shows the configuration of two such segments in 3-D space. Then a gap function (g) is defined to measure the distance of the measured segment to reference segment by the following equation;

$$g = \left(\underline{X}^{p} - \underline{X}^{cm}\right) \bullet \underline{N}^{cm} \qquad \dots (1)$$

And the corresponding gap vector, for this reference segment, is defined by

$$\underline{g} = g\underline{N}^{cm} \qquad \dots (2)$$

where, $X^{cm}$ and $N^{cm}$ are the position vector of the centroid of reference segment, cm, and its unit normal vector, respectively. $X^{p}$ denotes the position vector of a point, *p* obtained by the projection of the centroid of the reference segment onto the measured segment. Consequently, the gap function and the corresponding gap vector describe the relative distance of a measured segment to the reference segment. The gap function, as well as this distance returned by, depends on both the chosen point for projection, $X^{cm}$ on the reference segment, and the projection direction $N^{cm}$. It should be noted that the projection point should be located within the geometric boundary of the measured segment.

Assuming that there are *m* number of reference segments constituting the reference surface, the average relative distance of corresponding measured segments to the reference surfaces can be expressed by,

$$g_{mean} = \frac{1}{m}\sum_{i=1}^{m} g_i \qquad \dots (3)$$

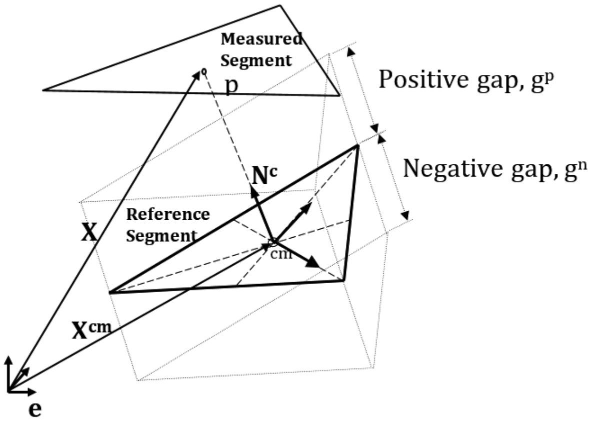

Fig. 3 — The schematics showing the definition of gap function (g) to obtain the difference between comparison geometries.

This quantity is called as the mean deviation. A standard deviation of relative distances for each measured segment to the corresponding reference segment may be defined as,

$$g_{\sigma} = \sqrt{\sum_{i=1}^{m}\left(\frac{g_i - g_{mean}}{m}\right)^2} \qquad \dots (4)$$

Finally, a gap tolerance may be defined to determine the percentage of measured segments whose relative distance is less than a definite amount. This gap tolerance may be specified for both positive and negative values of gap function, $g^p$, and $g^n$ respectively. Consequently, both upper and lower gap tolerance values determine the allowable deviation band concerning the reference surface and the corresponding percentile distribution for the allowable deviation of the measured surface. This projection technique can be applied to different mesh dimensions in FEA. Figure 4 shows an example flowchart of this technique for a real part. Firstly, the presented method calculates the geometric centroid of each element for both reference and measured surfaces through the geometry of the element. Secondly, the centroid of the whole geometry is determined using element centroids for both surfaces. Then, the centroid difference in the design space is obtained through a global coordinate system. At last, the measured surface is translated as the difference of the centroids. As a result, two geometries become localized by superposing geometric centroids.

Surfaces can have different mesh designs or mesh numbers. Hence it is hard to make a relation between meshes, and the process becomes time-consuming. An example of this situation can be seen in Fig. 5. Using the proposed methodology, this stage of localization can be eliminated by superposing the centroids of the surfaces.

### 2.2 Application Study

In this study, a roof stiffener stamping process is investigated as an application. Roof stiffener parts are designed to provide safety in rollover events. This part has a shallowly curved geometry, and the forming stroke of the part is approximately 12 mm causing the elastic strain to become dominant, and hence, springback becomes more significant.

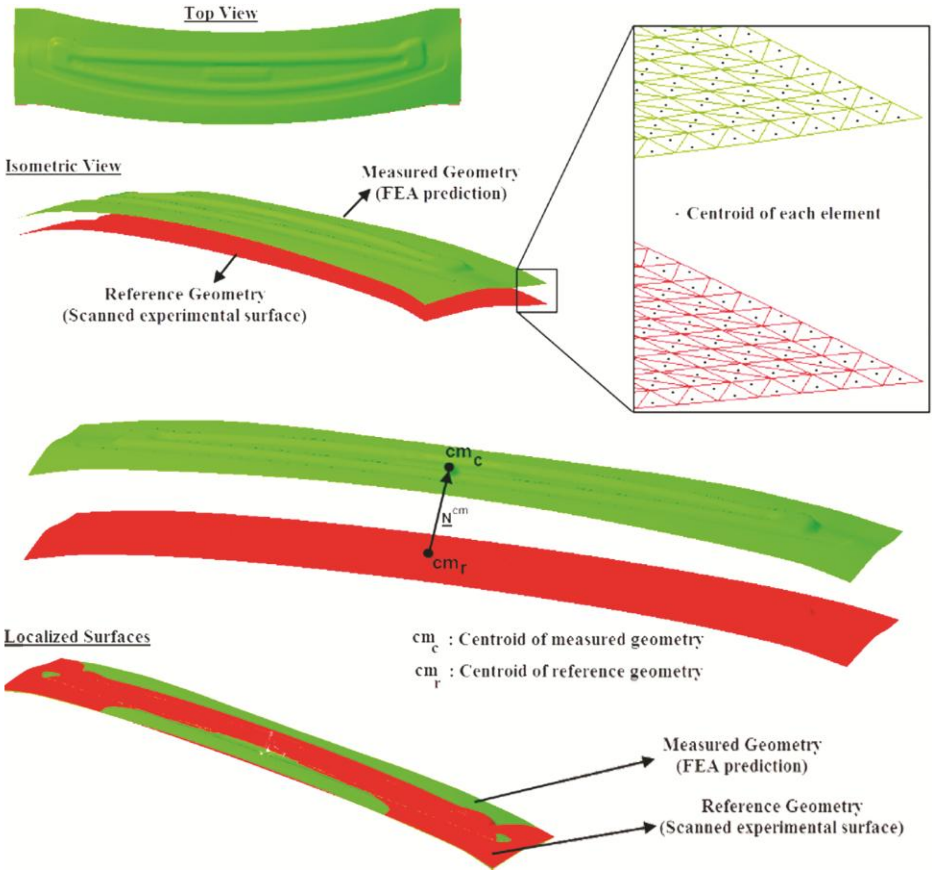

Fig. 4 — Application example of presented methodology on a real part.

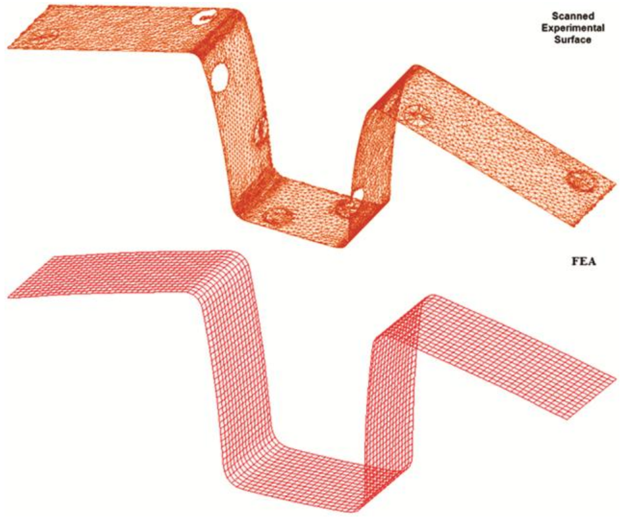

Fig. 5 — Mesh design difference between FEA and scanned experimental surfaces.

However, the material of the roof stiffener is a Dual-Phase (DP) advanced high strength steel with 1 mm gauge thickness causing the springback behavior to become complex and distributed to all part geometry. This part is chosen as an application study to improve the effectiveness of the proposed surface comparison methodology in real parts having complex geometric behavior. Figure 6 shows the geometry and location of the roof stiffener part. The initial sheet part was stamped by a hydraulic press. Die tools of the roof stiffener stamping process can be seen in Fig. 7. The product geometry was transferred into a computer environment using optical scanning, and this geometry is used as the experimental reference geometry in comparisons.

In the second step, this process was simulated using Ls-Dyna commercial software, and the part geometry is used as the measured surface with the experimental one. In FEA, Hill (1948) plasticity model[21] is used to determine the plastic behavior of the material. This model is to simulate forming processes with anisotropic material. Only transverse anisotropy can be considered. The yield function presented by Hill[21] can be written as in Eq. (5).

$$F(\sigma_{22}-\sigma_{33})^2+G(\sigma_{33}-\sigma_{11})^2+H(\sigma_{11}-\sigma_{22})^2+2L\sigma_{23}^2+2M\sigma_{31}^2+2N\sigma_{12}^2-1=0 \quad \ldots (5)$$

Where, $\sigma_{11}$, $\sigma_{22}$, and $\sigma_{33}$, refer to tensile yield stresses and $\sigma_{12}$, $\sigma_{23}$, and $\sigma_{31}$ are the shear yield

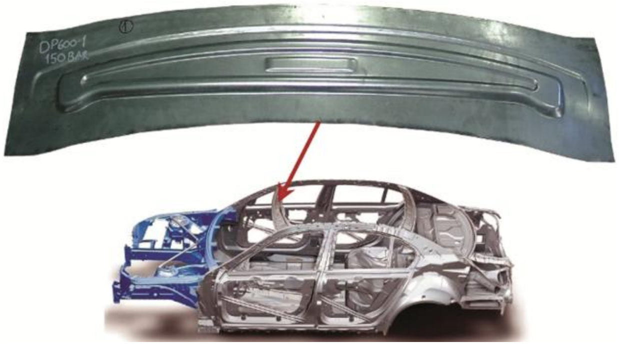

Fig. 6 — Roof stiffener geometry and its location in an automobile.

Fig. 7 — Die tools of roof stiffener stamping process.

stresses. The constants F, G H, L, M, and N are related to the yield stress and anisotropy parameters. This model can be written as in Eq. (6) for plane stress problems like sheet metal forming processes.

$$(G+H)\sigma_{11}^2 + 2H\sigma_{11}\sigma_{22} + (H+F)\sigma_{22}^2 + 2N\sigma_{12}^2 - 1 = 0 \quad \dots (6)$$

F, G, H, and N coefficients can be described as in Eq. (7).

$$\frac{H}{G} = r_0, \frac{H}{F} = r_{90}, \frac{H}{F+G} - \frac{1}{2} = \sigma_{45} \quad \dots (7)$$

where, $r_0$ and $r_{90}$ represent the anisotropy coefficients in rolling and transverse directions respectively while $\sigma_{45}$ is the yield stress in the diagonal direction. Mechanical properties of DP steel for the Hill-48 model can be seen in Table 1.

Table 1 — Mechanical properties of DP600 steel

| | |
|---|---|
| Young Modulus [GPa] | 207 |
| Yield Stress [MPa] | 420 |
| Strength Coefficient [MPa] | 1080.7 |
| Hardening Exponent | 0.16 |
| $r_0$ | 0.76 |
| $r_{45}$ | 0.93 |
| $r_{90}$ | 0.95 |

Table 2 — Finite element modelling parameters for roof stiffener stamping process

| | |
|---|---|
| Hardening model | Isotropic hardening |
| Flow rule | Holloman |
| Process temperature | 25°C |
| Punch stroke | 12 mm |
| Punch velocity | 2000 mm/s |
| Element formulation | Fully Integrated |
| Number of integration points | 7 |
| Time step size | $1.2 \times 10^{-6}$ |
| PC | Intel® Core™ i5-4310 CPU @ 2.00 GHz, 8 GB Ram |
| Computation time | 1682 s |

In FEAs, the die tools of the system are modeled as a rigid body and a half model is used due to the symmetry. Blank is modeled using shell elements with seven integration points through the thickness and element formulation is employed as fully integrated. Automatic surface to surface contact type is applied for the contacts between the blank and die tools. The friction coefficient for all contacts is set as 0.125. FE modelling parameters for the stamping process are summarized in Table 2. Die tools and FE model of the stamping process can be seen in Fig. 8. Results include spring back calculations are exported as a surface file for comparison with the experimental surface. Shape deviation analyses are used for surface evaluation. In shape deviation analysis, there must be a limit band to measure the difference between comparison surfaces. Stamping processes have other effects that cause shape distortions like press rigidity, die elasticity, dimensional factors, etc. It is hard to determine or measure these parameters. For this reason, limit bands in deviation analyses are used as sheet metal gauge thickness for stamping processes to present these factors, and limit bands are generally named as tolerance bands by design engineers (so in this study the tolerance band is used as 1 mm). In Fig. 9, a sample shape deviation analysis by using tolerance bands for a stamping operation can be seen. As it is seen from Fig. 9, red points represent the maximum positive difference areas and points in cyan color represent negative difference areas between comparison surfaces. The number of common nodes of the two surfaces within the tolerance bands shows the similarity of the surfaces.

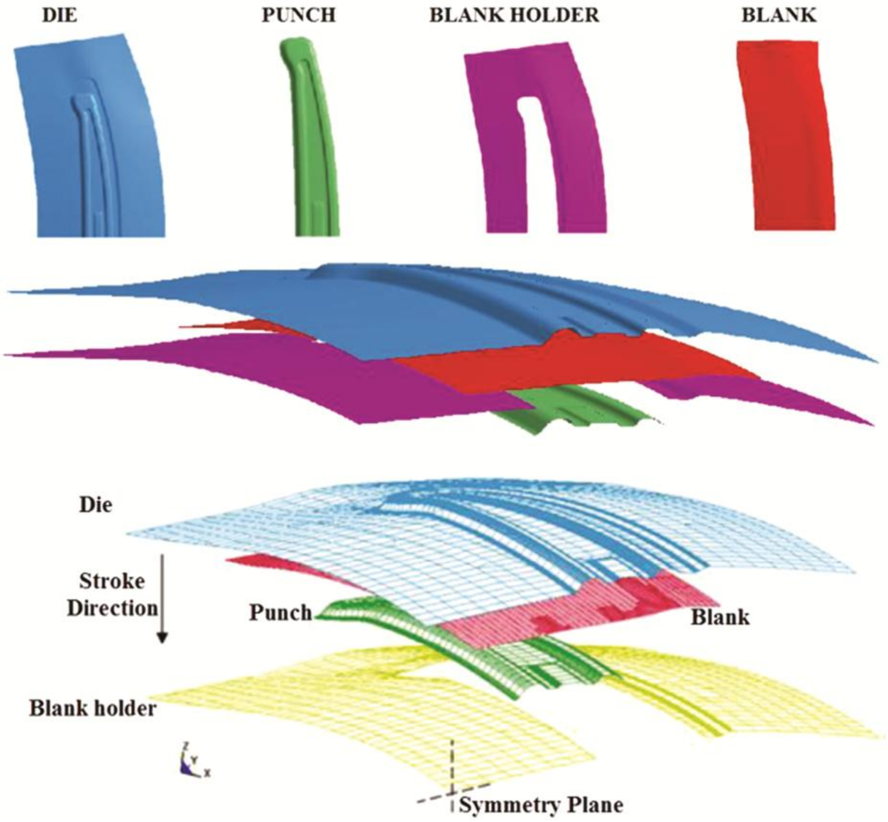

Fig. 8 — Die tool surfaces and finite element model of roof stiffener stamping process.

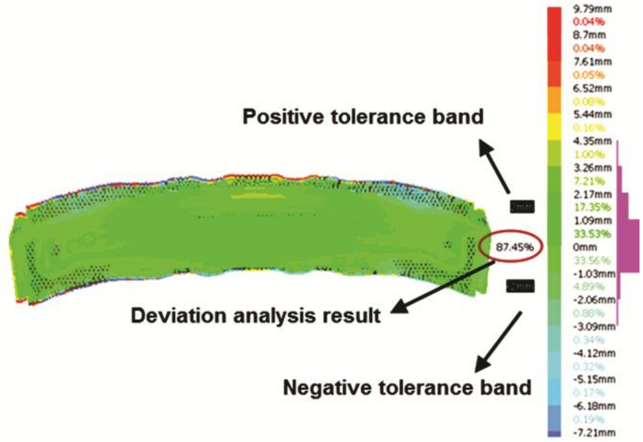

Fig. 9 — Shape deviation analysis example in CAD environment represents the similarity between comparison geometries.

In Fig. 10, the experimental surface is obtained by optical scanning method, transferred into a computer environment, and used as the reference surface. FE prediction results employing spring back geometries are compared with the reference geometry using three different methods. In the first method, best fit option of CAD software is used. In this method, similarity between the meshes of the reference and comparison surfaces are determined by the software using the neighborhood of the elements, and the comparison surface is located by using the best similarity obtained by the CAD surface. In the second method, named as axis superpose, the coordinate systems of the reference surface and the comparison surface are superposed in the CAD space. Lastly, the proposed method is used for localizing surfaces. The application of the proposed theory is implemented in a MATLAB script. Utilizing this code, once the user imports "stl" surface for localizing, the geometric centroids of these imported geometries are calculated, one of the surfaces is translated in the workspace according to the difference between the centroids, and finally, the localized surface is exported with new coordinates. Diagnostic time of proposed model for roof stiffener part is obtained as 193 seconds. As it can be seen in Fig. 11, the proposed methodology can localize the surfaces with an improved shape deviation. The proposed methodology localizes the elements in the design space with more common nodes within the tolerance bands by superposing the centroids of the surfaces. This situation can be confirmed by mean deviation values. The smallest

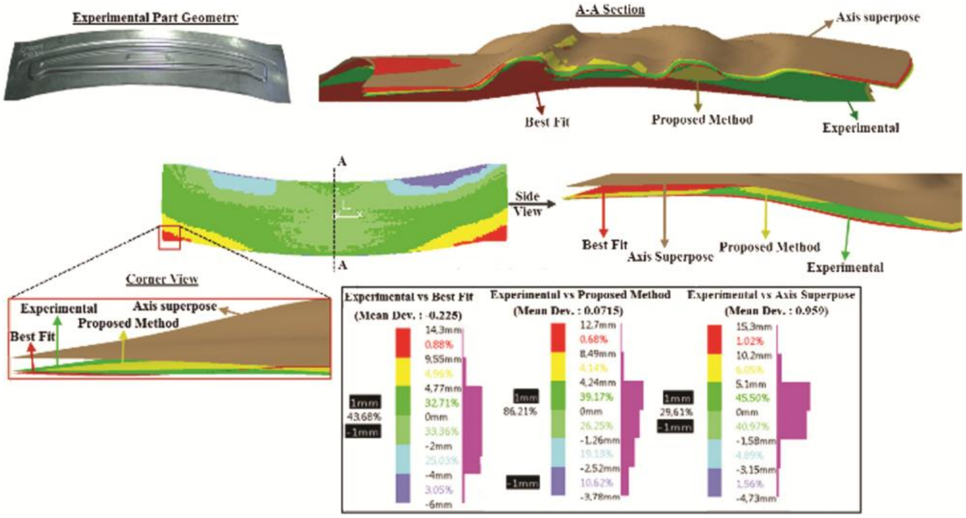

Fig. 10 — Comparison results with different localization techniques using shape deviation analyses in CAD environment.

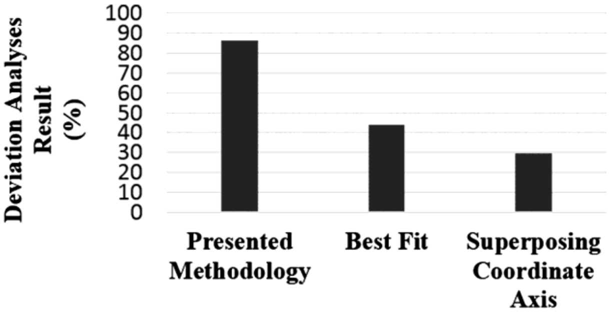

Fig. 11 — Comparison results by means of shape deviation analyses results for applied methodologies.

mean deviation is observed by the proposed methodology.

Long and elaborate introduction should be avoided. It should be brief and state the exact scope of the study in relation to the present status of knowledge in the field. Literature review should be limited strictly to what is necessary to indicate the essential background and the justification for undertaking the study. Whole introduction should be written in Present perfect tense.

## 3 Results and Discussion

In the automotive industry, especially passenger cars should have ergonomic and aerodynamic features. Considering the increasing fuel prices, the importance of aerodynamic characteristics increases as well as the vehicle weight. In this context, various improvements have been made in vehicle body designs from past to present, to improve aerodynamic properties in the automotive industry. The new surfaces, designed to minimize air resistance, are more complex than the classic vehicle surfaces of the 1950s[22]. At the same time, the surfaces of structural sheet metal parts are becoming more complex in parallel with the development of production methods. Complex surfaces are surfaces that do not represent a classical geometry (circle, arc, etc.). Today, with the development of computer technology, design of complex surfaces has become easier in CAD software. For this reason, the application area of complex surfaces is also increasing[23].

A reference geometry is required to determine the accuracy of the results obtained from the FEA. Reference geometry is the sheet metal form that comes out of the die tools as a result of forming in these processes. In order to compare this geometry with FEA, it initially should be checked and transferred to the computer environment. To transfer the part geometries to the computer environment, various controls, and measurements should be performed. If the geometries to be compared are simple, the simulation results and product geometry can be compared only by taking measurements from the required regions. But, for the comparison process on freeform surfaces, comparison with such a measurement is not at the desired level of accuracy. For freeform surfaces, the surfaces to be compared must be positioned in a reference position. This reference position must be a parameter in the workspace that has the same meaning for both surfaces. For example, either the determined points of the two surfaces can be compared mutually or their coordinate systems can be correlated.

The control process required for the comparison of complex surfaces can be executed in two different ways as contact or non-contact. Contact measurements are realized on coordinate measuring devices like CMMs. The coordinate systems of the device and the working space of the CAD software should be superposed for measurements to be made by CMM devices.

Although contact measurement methods are useful, they can only give coordinate information of certain points on the surface. If it is desired to obtain information about the entire surface, it is necessary to scan the surface using non-contact measurement methods. Although there are many types of non-contact measurement methods, the most commonly used types are laser and optical scanning methods[24,25].

In the literature, the joint positioning of two geometries to be compared in design space is called localization. If the two surfaces to be compared have different geometries, the comparison process becomes even more complex. The methods described so far, take the measurement points from the design surface. Using these methods, a point-to-point relationship can be established between geometries, and such a relationship simplifies the calculations. These methods are generally used in probe-type CMMs. However, it may not always be possible to measure a surface relative to its original model. For example, if the laser scanning method is used to transfer a geometry to the computer environment, the data density is quite high, and the measurement points are taken from the specified distances instead of the original surface model. In this case, there is no clear relationship between the measuring surface and the original surface.

When the studies in the literature for the positioning of complex surfaces in space are examined, it is generally seen that the surfaces to be compared are overlapped at the specified reference points[11,16]. A Andersson[26] investigated the springback behavior of a vehicle body part with Trip700 material, numerically and experimentally. In this context, to compare the results of the FEA, the experimental surfaces were transferred to the computer environment and the springback was examined in the selected sections by overlapping the surfaces from the determined control points. In another study, S A Asgari *et al*.[27] investigated a complex geometry drawing process consisting of Trip material. In order to compare the FEA results with the experimental surfaces, they overlapped the surfaces at four selected points and performed the comparison process by making springback measurements from 10 determined points. L Tang *et al*.[28] studied the springback behavior in a forming process with AHSS material. In this context, the parts formed in the press are transferred to the computer environment and the FE results are compared by overlaying at the determined control points. X Peng *et al*.[29] investigated the springback behavior in an industrial forming process with DP600 material. The parts formed in the press are transferred to the computer environment by optical scanning and compared with the results of the FEA.

Since many of the sheet metal parts have complex surfaces today, comparing the modelling surfaces obtained during the design phase with the experimental surfaces plays a critical role in decision-making mechanisms in terms of method engineering. Comparisons should sensitively be realized. In the sheet metal forming industry, the deformity of complex surfaces does not only consist of certain regions but also exhibits a distribution behavior. For this reason, comparisons are made by considering all the two surfaces. In this context, industrial tolerance bands are used, considering the part tolerances. In the sheet metal forming industry, comparisons are made with surface compatibility analysis. The most critical parameter affecting these comparisons is the positioning of the surfaces.

As can be seen from the literature studies, this positioning can be done from certain points of the surfaces, as well as by overlaying the local coordinate systems of the surfaces. Although these methods are used frequently, they cannot effectively calculate the number of points located within the industrial tolerance bands for shape deviation analysis. At the same time, since the coordinating of coordinate systems or nodal points is performed by the user, the positioning of the surfaces causes time losses. To make an effective comparison, a code that positions freeform surfaces in design space has been developed within the scope of the study. Employing the developed code, the surfaces to be compared are positioned in design space according to their geometrical centroids, so that both surfaces are positioned more accurately than the positioning made as a result of superposing the coordinate systems. The origins of the surfaces to be compared may not be the same, and in such a case, superposing the coordinate systems in conventional methods causes both surfaces to be incorrectly positioned in design space. Every action to be taken to fix this situation brings with it extra time losses. The developed code both performs these operations automatically and since the surfaces are taken as a reference, positioning is performed accurately even if the coordinate systems are different.

## 4 Conclusion

In this study, a novel surface localization procedure is presented for sheet metal stamping parts. In the first stage, a gap function is used for minimizing the mean deviation of the surface comparison. Mean deviation shows the accuracy of the comparison which is required to be minimized. In the second stage, the calculation of surface centroids and the superposing step is performed for surface comparison. The proposed methodology can be used as an effective tool for die designing in the sheet metal industry. In sheet metal forming processes, springback is a critical geometric problem for reaching product dimensional tolerances, and it affects the die design stage directly since die tool surfaces should be compensated through springback distribution of the part. The proposed methodology localizes the surfaces more accurately than conventional methods. Hence, die designers get the most accurate localization position. In the sheet metal industry, springback compensation is performed on die tool surfaces, and die tools are re-designed using the difference between the geometries before and after springback. If the designer localizes the surfaces accurately, new (compensated) die surfaces will be obtained in a short time since the localization stage is one of the most time-consuming parts of the die surface compensation process. A roof stiffener stamping operation is used as an application study for validation of the presented method.

In comparisons, superposing surface coordinate axes, best-fit procedure, and the proposed methodology are used. As a result, the proposed method localizes the surfaces more accurately (mean deviation is approximately 0.07) than conventional methods due to deviation analysis. It is seen that the localization method is a critical step in die tool designing, hence accuracy can be higher than the design engineer thought. Accurate localization directly affects the manufacturing time of die tools. For example, in the application study of the manuscript, a design engineer localizes the surfaces using the best fit method surface with a compatibility rate of 43.68% while he needs to improve this rate to an acceptable level like 90% for validating the FEA reliability, in an application study. Design stages due to simulation parameters, material models, etc. should be re-checked, or die surface design should be regenerated. However, using an accurate localization technique, same surface compatibility rate becomes 86.21%. This difference in compatibility rates is only related with the localization methodology. In this case, compensation of this difference can easily be managed by following less time-consuming steps. The importance of localization technique can be clearly seen when mass production industries, like automotive, are considered.

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